(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 100 140 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
14.09.2005 Bulletin 2005/37

(51) Int Cl.[7]: **H01M 8/24**, H01M 8/02

(21) Application number: **00127081.8**

(22) Date of filing: **17.12.1998**

(54) Fuel cell and separator for the same

Brennstoffzelle und Separator

Pile à combustible et séparateur pour celle-ci

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: **18.12.1997 JP 36512997**
27.03.1998 JP 10045398
18.06.1998 JP 18992698

(43) Date of publication of application:
16.05.2001 Bulletin 2001/20

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
98124043.5 / 0 924 785

(73) Proprietor: **Toyota Jidosha Kabushiki Kaisha**
Toyota-shi, Aichi-ken 471-8571 (JP)

(72) Inventors:
- **Iwase, Masayoshi**
  Toyota-shi, Aichi-ken 471-5871 (JP)
- **Hamada, Hitoshi**
  Toyota-shi, Aichi-ken 471-5871 (JP)
- **Kawatsu, Shigeyuki**
  Toyota-shi, Aichi-ken 471-5871 (JP)
- **Mizuno, Seiji**
  Toyota-shi, Aichi-ken 471-5871 (JP)
- **Yoshimura, Joji**
  Toyota-shi, Aichi-ken 471-5871 (JP)

(74) Representative: **TBK-Patent**
Bavariaring 4-6
80336 München (DE)

(56) References cited:
EP-A- 0 281 949
EP-A- 0 967 675
WO-A-97/33331
JP-A- 10 106 594
US-A- 3 801 374
US-A- 4 542 079
US-A- 4 649 091
US-A- 5 686 199

- **PATENT ABSTRACTS OF JAPAN vol. 1995, no. 11, 26 December 1995 (1995-12-26) -& JP 07 230815 A (TOKYO ELECTRIC POWER CO INC:THE;OTHERS: 01), 29 August 1995 (1995-08-29)**
- **PATENT ABSTRACTS OF JAPAN vol. 011, no. 275 (E-537), 5 September 1987 (1987-09-05) -& JP 62 076260 A (ISHIKAWAJIMA HARIMA HEAVY IND CO LTD), 8 April 1987 (1987-04-08)**
- **PATENT ABSTRACTS OF JAPAN vol. 016, no. 074 (E-1170), 24 February 1992 (1992-02-24) -& JP 03 266365 A (NKK CORP), 27 November 1991 (1991-11-27)**
- **PATENT ABSTRACTS OF JAPAN vol. 016, no. 120 (E-1182), 26 March 1992 (1992-03-26) -& JP 03 289057 A (HITACHI LTD), 19 December 1991 (1991-12-19)**
- **PATENT ABSTRACTS OF JAPAN vol. 017, no. 549 (E-1443), 4 October 1993 (1993-10-04) -& JP 05 159790 A (TOKYO GAS CO LTD), 25 June 1993 (1993-06-25)**

EP 1 100 140 B1

Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a fuel cell having a separator in contact with a pair of electrodes interposing an electrolyte film.

2. Description of the Related Art

[0002] A fuel cell is known as an apparatus for converting fuel energy directly to electric energy. The fuel cell is generally designed to be provided with a pair of electrodes with an electrolyte film interposed therebetween and to generate energy from the space between the pair of electrodes by an electrochemical reaction of fuel gas, e.g. hydrogen, and oxygen-containing gas. In this reaction, fuel gas is supplied to contact the surface of one of the electrodes and oxygen-containing gas is supplied to contact the surface of another electrode. Energy can be drawn from the fuel cell in a highly efficient manner as long as fuel gas and oxygen-containing gas are supplied.

[0003] FIG. 14 is a perspective view showing the configuration of a stack structure 5 constituting a general fuel cell and FIG. 15 is an exploded perspective view showing the structure of a unit cell 10 as a basic unit of the stack structure 5 shown in FIG. 14. In general, the fuel cell, for example, of a polymer electrolyte type is constituted of the stack structure 5 as shown in FIG. 14. This stack structure 5 is produced by laminating a prescribed number of unit cells 10, then disposing collector plates 26, 27, insulating plates 28, 29 and end plates 40, 45 sequentially at both ends of the unit cells and then fastening these ends using, for example, bolts and nuts such that it is maintained in the state where a given pressure is applied in the direction (the direction indicated by the arrow) of the lamination of the unit cell. The collector plates 26, 27 are provided with output terminals 26A, 27A respectively which enable it to output the electromotive force generated in the fuel cell structured by the stack structure 5.

[0004] In such a fuel cell, a member called a separator is provided which serves as a gas passage and a collector electrode to supply fuel gas and oxygen-containing gas to the electrode surface. A straight type separator provided with a plurality of linear passage grooves has been conventionally used. Serpentine type separator in which one passage groove is bent (disclosed in Japanese Patent Application Laid-Open (JP-A) No. HEI 7-263003) and lattice type separators in which plural projections are arranged and a passage is formed by a gap between these projections have also been known.

[0005] The unit cell 10 as a basic unit of the stack structure 5 of FIG. 14, as shown in FIG. 15, includes a joint body (reaction electrode layer) 15 produced by sandwiching an electrolyte film 11 between a cathode 12 and an anode (not shown), and separators 20A, 20B (the lattice type is shown as example) disposed on both sides of the reaction electrode layer 15. Among these parts, the separators 20A, 20B are formed from a gas-impermeable electroconductive member. Plural ribs 22 formed of small projecting pieces are arranged on both surfaces 31 of the separators.

[0006] When these separators 20A, 20B are assembled in the fuel cell, the rib (not shown) formed on the surface of the separators 20A at the cathode side constitutes a passage for oxidizing gas supplied to the cathode 12. While the rib 22 formed on the surface 21 of the separator 20B at the anode side constitutes a passage for fuel gas supplied to the anode (not shown). Meanwhile the rib 22 formed on the surface 21 opposite to the above surface of the separator 20A constitutes a passage forfuel gas supplied to the anode (not shown) of another adjacent unit cell (not shown) and a rib (not shown) formed on the surface opposite to the above surface of the separator 20B constitutes a passage for oxidizing gas supplied to a still another adjacent unit cell (not shown). One separator, therefore, supplies both types of gas to adjacent reaction electrodes and prevents mixture of both gases.

[0007] Oxidizing gas flowing through the oxidizing gas passage is distributed into the reaction electrode layer exposed to the oxidizing gas passage, and is supplied to the cathode of the reaction electrode layer. Likewise, fuel gas flowing through the fuel gas passage is distributed into the reaction electrode layer exposed to the fuel gas passage, and is supplied to the anode of the reaction electrode layer. As a consequence the respective gas is used in the reaction electrode layer 15 for the electrochemical reaction to produce electromotive force.

[0008] Specifically, in the reaction electrode layer 15, the reactions indicated by the formula (1) and the formula (2) proceed at the anode and cathode sides respectively and, on the whole, the reaction indicated by the formula (3) proceeds.

$$H_2 \rightarrow 2H^+ + 2e^- \quad (1)$$

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O \quad (2)$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O \quad (3)$$

[0009] The serpentine type separator has a narrow gas inlet and a long gas passage, resulting in excellent gas diffusibility.

[0010] However, in the known serpentine type separator, a partial pressure of gas in the gas passage is not constantly uniform. Accordingly there is the possibility

that the performance of the fuel cell as a battery may be deteriorated.

[0011] In the lattice type separator, even if one passage is clogged due to, for example, flooding or the like, specifically, condensation of water, gas and produced water can flow into other passages. So this type has excellent drainage as well as high diffusibility of gas. However, in the known lattice type separator, the passages are distributed in forward and backward directions leading to the possibility of insufficient gas flow rate. A deficiency in gas flow rate interrupts diffusion of gas, which causes concentration polarization, resulting in deteriorated performance of the fuel cell as a battery.

[0012] In the case of using dry gas at a low humidity as the supply gas (fuel gas and oxygen-containing gas), drainage at the electrode side to which oxygen-containing gas is supplied is excessive. Hence there is the case where an electrolyte film is dried up. This gives rise to the possibility of deteriorating characteristics of the cell.

[0013] Further, the US patent No. 3,801,374 discloses an acid fuel cell using a separator plate having a plurality of pegs projecting from a bottom thereof and two ribs which divide the area where the pegs project into three regions which form a fluid channel that communicates the regions with each other. The width of the region between the pair of ribs is wider than the widths of the regions near the inlet portion and the outlet portion of the separator.

SUMMARY OF THE INVENTION

[0014] An object of the present invention is to enhance diffusibility of supply gas in a fuel cell and improve drainage while effecting an increase in flow rate.

[0015] The above object is attained by a fuel cell as defined in claim 1. The dependent claims define further developments of the fuel cell.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

FIG. 1 is a sectional view showing a typical structure of a unit cell constituting a fuel cell.
FIG. 2 is a sectional view showing a typical fuel cell using a unit cell as shown in FIG. 1.
FIG. 3 is a plan view of a separator which may be used in the fuel cell shown in FIG. 2.
FIG. 4 is a perspective view with a part in section showing the separator of FIG. 3.
FIGS. 5 and 6 are graphs each showing the relation between voltage and current density of a fuel cell.
FIG. 7 is a plan view of another separator which may be used in the fuel cell shown in FIG. 2.
FIG. 8 is a plan view of still another separator which may be used in the fuel cell shown in FIG. 2 so as to constitute a preferred embodiment of the invention.
FIG. 9 is a plan view of a cooling plate which may be used in the fuel cell shown in FIG. 2.
FIG. 10 is a graph showing the relation between voltage and current density of a fuel cell.
FIG. 11 is a plan view of another cooling plate which may be used in the fuel cell shown in FIG. 2.
FIG. 12 is a graph showing the relation between voltage and current density of a fuel cell.
FIG. 13 is a plan view of another separator and cooling plate which may be used in the fuel cell shown in FIG. 2.
FIG. 14 is a perspective view showing the configuration of a stack structure constituting a conventional fuel cell.
FIG. 15 is an exploded view showing a unit cell as a basic unit of FIG. 14.

DETAILED DESCRIPTION OF THE INVENTION

[0017] A polymer electrolyte fuel cell (hereinafter simply called "fuel cell") of the present invention has a stack structure using a unit cell as a basic unit. FIG. 1 is an explanatory view showing a typical section of a unit cell 50. The unit cell 50 of the fuel cell is formed of an electrolyte film 51, an anode 52, a cathode 53 and separators 100A, 100B.

[0018] The anode 52 and the cathode 53 constitute gas diffusion electrodes for interposing the electrolyte film 51 between both sides to form a sandwich structure. This sandwich structure is further interposed between the separators 100A, 100B which constitute passages of fuel gas and oxygen-containing gas between themselves and the anode 52 and the cathode 53 respectively. A fuel gas passage 100AP is formed between the anode 52 and the separator 100A and an oxygen-containing gas passage 100BP is formed between the cathode 53 and the separator 100B.

[0019] Fig. 1 shows that each of separators 100A, 100B has a passage only on one surface thereof. Actually passages are formed on both surfaces and these separators respectively serve as the separator for an adjacent unit cell. Specifically, these separators 100A, 100B form the fuel gas passage 100AP between each one face of them and the anode 52 and form 100BP between each other face of them and a cathode of an adjacent unit cell. In this manner, the separators 100A, 100B form a gas passage between themselves and the gas diffusion electrode and serves to separate the streams of fuel gas and oxygen-containing gas in combination with an adjacent unit cell. When the unit cells 50 are laminated to form a stack structure, a passage is formed on each one face only, which is in contact with the gas diffusion electrode, of two separators positioned at both sides of the stuck structure to form a passage.

[0020] Here, the electrolyte film 51 is a proton-conductive ion exchange film formed of a solid polymer material, e.g. a fluororesin, and exhibits high electroconductivity in a moistened condition. In this embodiment,

a Nafion film (manufactured by Du Pont) is used. Platinum or an alloy composed of platinum and other metals is applied as a catalyst to the surface of the electrolyte film 51. In order to apply the catalyst, the following method is adopted by preparing carbon powder carrying platinum or an alloy composed of platinum and other metal, dispersing the carbon powder carrying this catalyst in a proper organic solvent, adding an electrolyte solution in an appropriate amount to the solvent to form a paste and performing screen-printing on the electrolyte film 51.

[0021] The carbon powder carrying a platinum catalyst is prepared by the following method. First, a platinic acid solution is mixed with sodium thiosulfate to produce a solution of a platinum sulfite complex. A hydrogen peroxide solution is added dropwise while stirring the solution to precipitate colloidal platinum particles in the solution. Next, the resulting solution is stirred while to this solution is added carbon black (for example, Vulcan XC-72™ (CABOT in USA) or Denka Black™ (Denki Kagaku Kogyo K.K) to allow a platinum powder to adhere to the surface of carbon black. Then, carbon black to which platinum particles adhere is separated from the solution by filtration either under reduced pressure or under pressure and the separated carbon black is washed in demineralized water repeatedly, and then thoroughly dried at a room temperature. Then the carbon black coagulated through the drying process is crushed using a crusher and heated at 250 to 350°C for about 2 hours in a hydrogen reducing atmosphere to reduce platinum adsorbed to carbon black and to remove chlorine remaining unremoved thereby producing a carbon powder carrying a platinum catalyst.

[0022] The carrier density of platinum on carbon black (the ratio of the amount of platinum on carbon to the amount of carbon) can be controlled by changing the ratio of the amount of platinic acid chloride to the amount of carbon black and hence a platinum catalyst having an optional carrier density can be obtained. The method for the production of the platinum catalyst is not limited to the above method. A platinum catalyst produced by other methods may be used as far as sufficient catalytic activity is obtained in these methods.

[0023] The foregoing explanations are given for the case of using platinum as a catalyst. Apart from platinum, an alloy catalyst comprising an alloy composed of platinum as a first component and one or more components selected from ruthenium, nickel, cobalt, indium, iron, chromium, manganese, and the like as a second component may be used.

[0024] Both the anode 52 and cathode 53 are formed of carbon cloth woven from carbon fibers. It is also preferable to make these electrodes by using carbon paper or carbon felt instead of the carbon cloth.

[0025] The electrolyte film 51, the anode 52 and the cathode 53 are integrated by thermocompression. Specifically, the electrolyte film 51 coated with a catalyst such as platinum is interposed between the anode 52 and the cathode 53 and these materials are thermocompressed in the heat at a temperature ranging form 120 to 130°C. As the method for the integration of the electrolyte film 51, the anode 52 and the cathode 53, other than thermocompression, adhesive method may be used. When the electrolyte film 51 is interposed between the anode 52 and the cathode 53, if the electrode and the electrolyte film 51 are joined using a proton electroconductive solid polymer solution (for example, Nafion solution, manufactured by Aldrich Chemical), the proton electroconductive solid polymer solution acts as an adhesive in the course of its solidification whereby the electrode and the electrolyte film 51 are secured.

[0026] The separators 100A, 100B are made from a gas-impermeable electroconductive material, for example, fine carbon which is made gas-impermeable by compressing carbon.

[0027] The foregoing descriptions are given to explain the structure of the unit cell 50 which is a base unit. When it is actually fabricated as a fuel cell, the separator 100A, the anode 52, the electrolyte film 51, the cathode 53, and the separator 100B are laminated in this order and a set of these materials is laminated in plural (for instance, 100 sets). Then, collector plates composed of fine carbon or a steel plate are disposed on both ends of the above laminated body to form a stack structure.

[0028] Next, a fuel cell will be explained with reference to FIGS. 2 to 13. It is to be noted that a fuel cell using the separator shown in FIG. 8 is a preferred embodiment of the invention and that a fuel cell using the separator shown in FIG. 3, 7 or 12 is outside the scope of the claims.

[0029] In the fuel cell FB10, as shown in FIG. 2, a separator 300A, an anode 72, an electrolyte film 71, a cathode 73, and a separator 300B are laminated in this order and a set of these materials is laminated in plural (3 sets in FIG. 2) wherein a cooling plate 30 is inserted every lamination of the set. A combination of three unit cells 70 having such a structure and the cooling plate 30 is laminated in plural, for example, 100 sets. The cooling plate 30 is formed of the same material as those of the separators 300A, 300B and serves to control the temperature of a fuel cell FB10 by supplying and withdrawing external cooling water.

[0030] FIG. 3 is a plan view of a separator 300A which may be used in the fuel cell FB10. FIG. 4 is a perspective view of the half part of the separator 300A. As shown in FIGS. 3 and 4, the separator 300A is formed as a square plate material in which square holes 301, 303 with a large size are formed in the vicinity of two opposite side edges respectively and square holes 305, 306, 307, 308 with a small size in the vicinity of other two side edges respectively.

[0031] The holes 301, 303 with a large size, when unit cells are laminated, form two passages for supplying and withdrawing cooling water which passages penetrate the fuel cell 310 in the direction of the lamination. The two holes 305, 308 with a small size which are op-

posed to each other on a diagonal line, when unit cells are laminated, form two passages for supplying and exhausting fuel gas which passages penetrate the fuel cell 310 in the direction of the lamination. The remainder two holes 306, 307 with a small size, when unit cells are laminated, form passages for supplying and exhausting oxygen-containing gas which passages penetrate the fuel cell in the direction of the lamination.

[0032] In further inside section than a peripheral plane of the separator 300A in which plane these holes 301, 303, and 305, 306, 307, 308 are formed, a stepped surface 311 one step lower than the above peripheral plane is formed. On the stepped surface 311, projections 313 which are a rectangular parallelepiped with 2 mm wide, 2 mm long and 1 mm high and are regularly arranged lattice-like are formed in plural.

[0033] On the stepped surface 311, two linear rib pieces 355, 356 arranged so as to divide the width of the stepped surface 311 into three equal parts are formed. Each of the rib pieces 355, 356 has the same height of 1 mm as that of the projection 313, a width of 1mm and a length shorter than the side width of the stepped surface 311. The rib pieces 355, 356 are formed such that directionally inverse ends 355a, 356a of the rib pieces 355, 356 respectively are connected to the peripheral plane of the separator 300A and the other ends 355b, 356b of the rib pieces 355, 356 respectively are positioned away from the peripheral plane at the given distance S. The distance S is the same as the width W of a passage formed by the rib pieces 355, 356.

[0034] The stepped surface 311 is divided into three areas by the rib pieces 355, 356. These areas are communicated with each other and, as a consequence, one large wavy (bent form) passage is formed on the stepped surface 311. Both ends of the passage are connected to certain positions of the holes 305 and 308. Since no partitioned wall is not present between the ends of the passage and the holes 305, 308 respectively, the wavy passage is communicated with the holes 305, 308- As a result, fuel gas from the passage for supplying and exhausting fuel gas which passage comprises the holes 305, 308 is supplied to and exhausted from the above passage on the stepped surface 311.

[0035] According to the separator 300A having such a structure, in general, a combination of the rib pieces 355, 356, the stepped surface 311 and the surface of the anode 72 forms a wavy passage (large passage) for fuel gas. In details, a combination of the projections 313, the stepped surface 311 and the surface of the anode 72 forms passages (small passages) for fuel gas which are branched in a plurality of directions. These passages of fuel gas correspond to the fuel gas passages 100AP shown in FIG. 1.

[0036] Also on the other surface (the back surface in FIG. 6) of the separator 300A, a stepped surface, projections and rib pieces (both not shown) having the same shapes as those of the stepped surface 311, the projections 313 and rib pieces 355, 356 respectively are formed. A combination of these stepped surface, projections, rib pieces and the surface of the cathode 73 forms a passage of oxygen-containing gas. Oxygen-containing gas from the passage for supplying and exhausting oxygen-containing gas which passage has the hole 306, 307 is supplied to and exhausted from the passage of oxygen-containing gas. Such a passage of oxygen-containing gas corresponds to the oxygen-containing gas passage 100BP shown in FIG. 1.

[0037] As explained in detail, in the fuel cell 310 of this embodiment, a wavy passage of fuel gas is formed between the holes 305 and 308 and plural projections 313 are formed in the passage. The formation of the rib pieces 355, 356 ensures that the entire width of the passage communicated with the holes 305, 308 as the inlet and outlet of fuel gas is decreased. As the narrow width of the passage increases the flow velocity of fuel gas, concentration polarization can be reduced by enhancing diffusibility of fuel gas. Also in the case of oxygen-containing gas, the same structure is made in which the concentration polarization can be reduced by enhancing diffusibility of fuel gas.

[0038] In this fuel cell FB10, the total length of the passage is elongated by forming the gas passage into the wavy shape. It is therefore possible to prevent the dry-up of the electrolyte film even if dry gas is used as the supply gas including the fuel gas and the oxygen-containing gas. In general, on the cathode 323, water is created by an electrode reaction and there is the case where the drainage of the created water is excessive causing the electrolyte film to be dried-up. However in the fuel cell using the separator of this embodiment, if the total length of the passage is long, supply gas is gradually moistened as it goes forward and hence the electrolyte film 321 is prevented from being dried-up. Thus, the actions by which concentration polarization is reduced and the dry-up of the electrolyte film 321 is prevented can improve the performance of the fuel cell FB10.

[0039] Next, the fuel cell FB10 will be explained in comparison with fuel cells of related art technologies. Here, as the fuel cells in the related art, two types, a fuel cell using a lattice type separator and a fuel cell (so-called serpentine type) provided with a wavy passage groove were prepared. Also, as operating conditions, two conditions were adopted, specifically, a first condition using wet gas (the humidity of fuel gas and oxygen-containing gas were 100% and 90% respectively) and a second condition using dry gas (humidity of fuel gas and oxygen-containing gas were 100% and 30% respectively).

[0040] FIG. 5 is a graph showing the relation between voltage and current density when a fuel cell is operated in the first condition. FIG. 6 is a graph showing the relation between voltage and current density when a fuel cell is operated in the second condition. In FIGS. 5 and 6, the curve A indicates the relation between voltage and current density for the fuel cell FB10, the curve B indi-

cates the relation between voltage and current density for the fuel cell of the lattice type of related art technologies and the curve C indicates the relation between voltage and current density for the fuel cell of the serpentine type of related art technologies.

[0041] As shown in FIG. 5, under the condition using the wet supply gas, the fuel cell FB10 had superior characteristics over all range of current density in contrast with the fuel cells of related art. A voltage reduction particularly at high current densities (above 0.5 A/cm^2) is small. An improvement in the gas diffusibility was, thus, confirmed.

[0042] As shown in FIG. 6, under the condition using the dry supply gas, the fuel cell FB10 had superior characteristics over all range of current density in contrast with the fuel cells of related art. In particular, under the condition using dry gas, a voltage reduction is significantly smaller than that of the fuel cell of the lattice type of related art. An improvement in prevention of the dry-up of the electrolyte film 321 was, thus, confirmed.

[0043] In the fuel cell FB10, the width (which corresponds to the distance S between the ends 355b, 356b of the rib pieces 355, 356 and the peripheral plane section) of the turning section in the wavy passage which section is formed by the rib pieces 355, 356 is the same as the width W of the passage. Instead of this structure of the separator, the structure of the separator shown in FIG. 7 may be adopted. The separator 400A shown in FIG. 7 has the same shape as that of the separator 300A except that the total length of rib pieces 455, 456 is longer than that of the rib pieces 355, 356 by 1.5 mm (1.5 times the width of the projection). In such a structure, the width of the passage corresponding to the distance Sa between the ends 455b, 456b and the peripheral plane is narrower than the width W of the passage formed by the rib pieces 455, 456.

[0044] Accordingly, since the width of the turning section is small, the flow rate of gas at the turning section can be increased. Because of this, the diffusibility of supply gas is further improved, leading to increased flow rate which improves water drainage.

[0045] Moreover, the structure shown in FIG. 8 may be adopted in which the widths W1, W2 and W3 structured by the rib pieces 455, 456 of a first passage, second passage and third passage respectively decrease every order (that is; these widths have the relation: $W1 \geqq W2 \geqq W3$). It is noted that, in the separator 500A in FIG. 8, the width S1 of the turning section from the first passage is narrower than the width W1 of the first passage and the width S2 of the turning section from the second passage is narrower than the width W2 of the second passage.

[0046] The flow rate can be further increased by the aforementioned two devices that the width of the passage is made narrower with a descent to a downstream side and the width of the turning section is made narrower than the width of the passage just before the turning section. This enhances diffusibility of supply gas whereby the improvement in drainage due to an increase in the flow rate can be more effected.

[0047] Next, the shape of a cooling plate will be explained.

[0048] FIG. 12 is a plan view of a cooling plate 2300. The cooling plate 2300 is formed as a square plate material. Like the above separators, square holes 2301, 2303 with a large size are formed in the vicinity of two opposite side edges respectively and square holes 2305, 2306, 2307, 2308 with a small size in the vicinity of other two side edges, respectively.

[0049] The holes 2301, 2303 with a large size, when unit cells are laminated, form two passages for supplying and withdrawing cooling water which passages penetrate the fuel cell in the direction of the lamination. The two holes 2305, 2308 with a small size which are opposed to each other on a diagonal line, when unit cells are laminated, form two passages for supplying and exhausting fuel gas which passages penetrate the fuel cell in the direction of the lamination. The remainder two holes 2306, 2307 with a small size, when unit cells are laminated, form passages for supplying and exhausting oxygen-containing gas which passages penetrate the fuel cell in the direction of the lamination.

[0050] In more inside section than a peripheral plane of the cooling plate 2300 in which plane these holes 2301, 2303, 2305, 2306, 2307, 2308 are formed, a stepped surface 2311 one step lower than the above peripheral plane is formed. On the stepped surface 2311, projections 2313 which are a rectangular parallelepiped with 2 mm wide, 2 mm long and 1 mm high and are regularly arranged lattice-like are formed in plural. Since no partitioned wall is not present between the stepped surface 2311 and the passage for supplying and draining cooling water and the holes 2301, 2303 with a large size, cooling water from the holes 2301, 2303 is supplied to and drained from the passage formed by the projections 2313 on the stepped surface 2311.

[0051] In the fuel cell using the cooling plate constituted in the above manner, the passages of cooling water which passages are branched in plural directions are formed by a plurality of projections 2313 formed on the cooling plate 2300. This improves the diffusibility of cooling water whereby the flow distribution of cooling water can be uniformed. Also, a heating surface area can be increased by the effect of the projections 2313 having such a shape.

[0052] Therefore, according to the fuel cell using the above cooling plate, the cooling performance can be improved. Flooding of a gas diffusion electrode and dry-up of the electrolyte film can be therefore restricted. Hence the performance of the cell can be improved.

[0053] FIG. 10 shows the relation between voltage and current density for the fuel cell using the above cooling plate.

[0054] In the figure, the curve A indicates the relation between voltage and current density for the fuel cell of this embodiment and the curve B indicates the relation

between voltage and current density for a fuel cell of related art. The fuel cell of related art is a fuel cell having a straight type cooling plate formed with a plurality of linear passage groove.

[0055] As shown in FIG. 10, it was observed that the fuel cell using the above cooling plate was reduced in voltage drop and improved in the performance of the cell.

[0056] Next, the shape of another cooling plate will be explained. The cooling plate has almost the same shape as that of the separator 300 explained above. The cooling plate will be explained in detail.

[0057] FIG. 11 is a plan view of the cooling plate 3300. As shown in FIG. 11, the cooling plate 3300 is formed as a square plate material. Like the cooling plate 2300, square holes 3301, 3303 with a large size are formed in the vicinity of two opposite side edges respectively and square holes 3305, 3306, 3307, 3308 with a small size in the vicinity of other two side edges respectively.

[0058] In the cooling plate 3300, the holes 3301, 3303 with a large size, when unit cells are laminated, form two passages for supplying and exhausting oxygen-containing gas which passages penetrate the fuel cell in the direction of the lamination. The opposite two holes 3305, 3308 with a small size on a diagonal line, when unit cells are laminated, form two passages for supplying and draining cooling water which passages penetrate the fuel cell in the direction of the lamination. The remainder two holes 3306, 3307 with a small size, when unit cells are laminated, form passages for supplying and exhausting fuel gas which passages penetrate the fuel cell in the direction of the lamination.

[0059] In more inside section than a peripheral plane of the cooling plate 3300 in which plane these holes 3301, 3303, 3305, 3306, 3307, 3308 are formed, a stepped surface 3311 one step lower than the above peripheral plane is formed. On the stepped surface 3311, projections 3313 which are a rectangular parallelepiped with 2 mm wide, 2 mm long and 1 mm high and are regularly arranged lattice-like are formed in plural.

[0060] On the stepped surface 3311, two linear rib pieces 3355, 3356 arranged so as to divide the width of the stepped surface 3311 into three equal parts are formed. The rib pieces 3355, 3356 each have the same height of 1 mm as that of the projection 3313, a width of 1mm and a length shorter than the side width of the stepped surface 3311. The rib pieces 3355, 3356 are formed such that directionally inverse ends 3355a, 3356a of the rib pieces 3355, 3356 respectively are connected to the peripheral plane of the cooling plate 3300 and the other ends 3355b, 3356b of the rib pieces 3355, 3356 respectively are positioned away from the peripheral plane at the given distance X. The distance X is narrower than the width Y of a passage formed by the rib pieces 3355, 3356 in this embodiment. As for the magnitude of the distance X and the width Y, though the width Y is not necessarily required to be larger, the difference of the both causes the difference in the cooling performance. The difference in the cooling performance will be described later.

[0061] The stepped surface 3311 is divided into three areas by the rib pieces 3355, 3356. These areas are communicated and, as a consequence, one large wavy (bent form) passage is formed on the stepped surface 3311. Both ends of the passage are connected to certain positions of the holes 3305 and 3303. Since no partitioned wall does not present between the ends of the passage and the holes 3305, 3308 respectively, the wavy passage is communicated with the holes 3305, 3308.

[0062] As a result, cooling water from a passage for supplying and draining cooling water which passage comprises the holes 3305, 3308 is supplied to and exhausted from the above passage on the stepped surface 3501.

[0063] According to such a structure, in general, a combination of the rib pieces 3355, 3356, the stepped surface 3311, and the surface of the gas diffusion electrode which surface is opposite to the electrolyte film forms a wavy passage (large passage) for cooling water. In details, a combination of the projections 3313, the stepped surface 3311 and the surface of the gas diffusion electrode which surface is opposite to the electrolyte film forms passages (small passages) for cooling water which are branched in a plurality of directions.

[0064] Cooling water is branched in plural directions by plural projections 3313 formed on the cooling plate 3300 having the above structure to thereby improve the diffusibility of cooling water. Also, the width of entire passage is narrowed to increase the flow rate of cooling water by the rib pieces 3355, 3356.

[0065] In the fuel cell using the above cooling plate, the cooling (temperature regulation) performance can be more improved due to improved diffusibility and flow rate. This allows the performance of the cell to be improved.

[0066] Moreover, in this fuel cell , the distance X corresponding to the width of the turning section of the wavy passage of cooling water is narrower than the width Y of the passage. The diffusibility and flow rate of cooling water can be improved by this turning section. The cooling (temperature regulation) performance can be more improved due to improved diffusibility and flow rate. This allows the performance of the cell to be more improved.

[0067] The following explanations are made to compare the performances of fuel cells obtained by altering the width (which corresponds to the distance X and hereinafter the width of the turning section is also represented by X) of the turning section of the passage of cooling water. Here, for comparison, a first structure in which the width X of the turning section of the passage of cooling water is narrower than the width Y of the passage (this embodiment), a second structure in which the width X of the turning section is equal to the width Y of the passage and a third structure in which the width X of the turning section is larger than the width Y of the

passage are prepared.

[0068] FIG. 12 is a graph showing the relation between voltage and current density for the fuel cells having the above structures. In the figure, the curves F, G and H correspond to the relations for the fuel cells having the first, second and third structures respectively.

[0069] As shown in FIG. 12, the fuel cell having the first structure in which the width X of the turning section of the passage of cooling water is narrower than the width Y of the passage, as shown FIG. 15, has superior characteristics compared to the fuel cells having other two structures over all current densities in a measurement range. It is confirmed that a voltage drop particularly at high current densities (above 0.5 A/cm^2) is small. The fuel cell having the second structure in which the width X is equal to the width Y has the second superior cell characteristics.

[0070] Therefore, it is also confirmed from the results shown in FIG. 12 that the performance of the fuel cell can be improved by making the width X of the turning section in the passage of cooling water narrower than the width Y of the passage .

[0071] The separator 300A and the cooling plate 2300 which are mounted on the fuel cell respectively form one continuous passage by using rib pieces 355, 356 (2355, 2356). A separator or cooling plate having the following shape may be used instead of the above separator and cooling plate. Specifically, as shown in FIG. 13, in the separator or cooling plate of this embodiment, rib pieces 655, 656 in which both ends of each of these rib pieces are designed to be away from the peripheral plane is formed on the bottom of a passage and a passage is branched through the gap between the rib pieces 655, 656 and both peripheral planes. This structure also makes it possible to form a large passage having bent portions between the inlet 601 and outlet 603 of cooling water, so that the performance of the fuel cell can be improved.

[0072] In the fuel cells mentioned above, as the material for forming the separator, fine carbon which is made impermeable by compressing carbon is used. Different materials may be used. For instance, the separator may be made from moulded carbon, burned carbon or a metal material. When a metal material is used to form the separator, it is desirable to select a metal having sufficient corrosion resistance. Alternatively, the surface of a metal may be coated with a material having sufficient corrosion resistance. Particularly when the separator is formed from a metal material, the production cost of a die greatly differ depending on the size, number and accuracy of the rib. If a rib having the form used in the aforementioned embodiments is used, the production cost of the die can be considerably lowered since the number of the ribs may be low and the ribs may not be small.

[0073] Moreover, in each of the aforementioned fuell cells, the case where the present invention is applied to a polymer electrolyte fuel cell is explained. The present invention can be applied to different types of fuel cell such as a phosphoric acid type fuel cell and a solid electrolyte fuel cell.

Claims

1. A fuel cell having a joint body produced by interposing an electrolyte member between a pair of electrodes, and a separator (500A) which holds the joint body, the separator (500A) comprising:

   a plurality of projections projecting from a bottom of the separator; and
   a rib portion (555, 556) which divides an area where the projections project into a plurality of regions and forms a fluid passage for fluid which flows through the separator, wherein the plurality of regions communicate with each other,

   characterized in that
   the width (W1, W2, W3) of each region is different, the width (W1) of the regions near an inlet portion of the fluid being wider than the width (W3) of the regions near an outlet portion of the fluid.

2. A fuel cell according to claim 1, wherein the number of the projections arranged in each region is different, the number of the projections near the inlet portion of the fluid being greater than the number of the projections arranged in the regions near the outlet portion of the fluid.

3. A fuel cell according to claim 1 or 2, wherein the width of the fluid passage is made narrower with a descent to a downstream side thereof.

4. A fuel cell according to any one of claims 1 to 3, wherein the fluid passage has a bent form.

5. A fuel cell (50) according to any one of claims 1 to 3, wherein the rib portion comprises at least one rib piece (555, 556).

6. A fuel cell (50) according to claim 5, wherein a width (S1, S2) of a turning section of the fluid passage defined by the rib piece (555, 556) is narrower than the width (W1, W2) of the region at the turning section, which is nearer to the inlet portion of the fluid.

7. A fuel cell according to any one of claims 1 to 6, wherein the fluid includes supply gas.

8. A fuel cell according to any one of claims 1 to 6, wherein the fluid includes a coolant.

9. A fuel cell according to any preceding claim, where-

in said fuel cell is a polymer electrolyte fuel cell type.

Patentansprüche

1. Brennstoffzelle, die einen Verbindungskörper, der durch Zwischenlegen eines Elektrolytelements zwischen ein Paar Elektroden erzeugt wird, und einen Separator (500A) hat, der den Verbindungskörper hält, wobei der Separator (500A) aufweist:

   eine Vielzahl von Vorsprüngen, die aus einem Unterteil des Separators hervorstehen; und
   einen Rippenabschnitt (555, 556), welcher eine Fläche teilt, in welcher die Vorsprünge in eine Vielzahl von Bereiche vorstehen und einen Fluiddurchgang für Fluid ausbildet, welches durch den Separator strömt, wobei die Vielzahl von Bereichen miteinander in Verbindung stehen,

   dadurch gekennzeichnet, dass
   die Breite (W1, W2, W3) jedes Bereichs verschieden ist, wobei die Breite (W1) der Bereiche nahe einem Einlassabschnitt des Fluids breiter als die Breite (W3) der Bereiche nahe einem Auslassabschnitt des Fluids ist.

2. Brennstoffzelle gemäß Anspruch 1, bei welcher die Anzahl der in jedem Bereich angeordneten Vorsprünge verschieden ist, wobei die Anzahl der Vorsprünge nahe dem Einlassabschnitt des Fluids größer als die Anzahl der in den Bereichen nahe dem Auslassabschnitt des Fluids angeordneten Vorsprünge ist.

3. Brennstoffzelle gemäß Anspruch 1 oder 2, bei welcher die Breite des Fluiddurchgangs mit einem Gefälle zu dessen stromabwärts gelegener Seite enger gemacht ist.

4. Brennstoffzelle gemäß einem der Ansprüche 1 bis 3, bei welcher der Fluiddurchgang eine gebogene Form hat.

5. Brennstoffzelle (50) gemäß einem der Ansprüche 1 bis 3, bei welcher der Rippenabschnitt mindestens ein Rippenstück (555, 556) aufweist.

6. Brennstoffzelle (50) gemäß Anspruch 5, bei welcher eine Breite (S1, S2) eines Umkehrabschnitts des Fluiddurchgangs, definiert durch das Rippenstück (555, 556), enger als die Breite (W1, W2) des Bereichs in dem Wendeabschnitt ist, welche dem Einlassabschnitt des Fluids näher ist.

7. Brennstoffzelle gemäß einem der Ansprüche 1 bis 6, bei welcher das Fluid Zufuhrgas enthält.

8. Brennstoffzelle gemäß einem der Ansprüche 1 bis 6, bei welcher das Fluid ein Kühlmittel enthält.

9. Brennstoffzelle gemäß einem vorhergehenden Anspruch, bei welcher die Brennstoffzelle eine Brennstoffzelle eines Polymer-Elektrolyt-Typs ist.

Revendications

1. Pile à combustible comportant un corps de liaison produit en intercalant un élément d'électrolyte entre une paire d'électrodes, et un séparateur (500A) qui maintient le corps de liaison, le séparateur (500A) comprenant :

   une pluralité de protubérances dépassant d'une partie inférieure du séparateur, et
   une partie de nervure (555, 556) qui divise une zone où les protubérances dépassent en une pluralité de régions et forme un passage de fluide pour un fluide qui circule au travers du séparateur, dans lequel la pluralité de régions communiquent les unes avec les autres,

   caractérisée en ce que
   la largeur (W1, W2, W3) de chaque région est différente, la largeur (W1) des régions proches d'une partie d'entrée du fluide étant plus large que la largeur (W3) des régions proches d'une partie de sortie du fluide.

2. Pile à combustible selon la revendication 1, dans laquelle le nombre des protubérances agencées dans chaque région est différent, le nombre des protubérances près de la partie d'entrée du fluide étant plus grand que le nombre des protubérances agencées dans les régions proches de la partie de sortie du fluide.

3. Pile à combustion selon la revendication 1 ou 2, dans laquelle la largeur du passage de fluide est rendue plus étroite avec une diminution vers le côté aval de celui-ci.

4. Pile à combustible selon l'une quelconque des revendications 1 à 3, dans laquelle le passage de fluide présente une forme courbée.

5. Pile à combustible (50) selon l'une des revendications 1 à 3, dans laquelle la partie de nervure comprend au moins un élément de nervure (555, 556).

6. Pile à combustible (50) selon la revendication 5, dans laquelle une largeur (S1, S2) d'une section de virage du passage de fluide défini par l'élément de nervure (555, 556) est plus étroite que la largeur (W1, W2) de la région au niveau de la section de

virage, qui est plus proche de la partie d'entrée du fluide.

7. Pile à combustible selon l'une quelconque des revendications 1 à 6, dans laquelle le fluide comprend un gaz d'alimentation.

8. Pile à combustible selon l'une quelconque des revendications 1 à 6, dans laquelle le fluide comprend un agent de refroidissement.

9. Pile à combustible selon l'une quelconque des revendications précédentes, où ladite pile à combustible est du type pile à combustible à électrolyte polymère.

FIG. 1

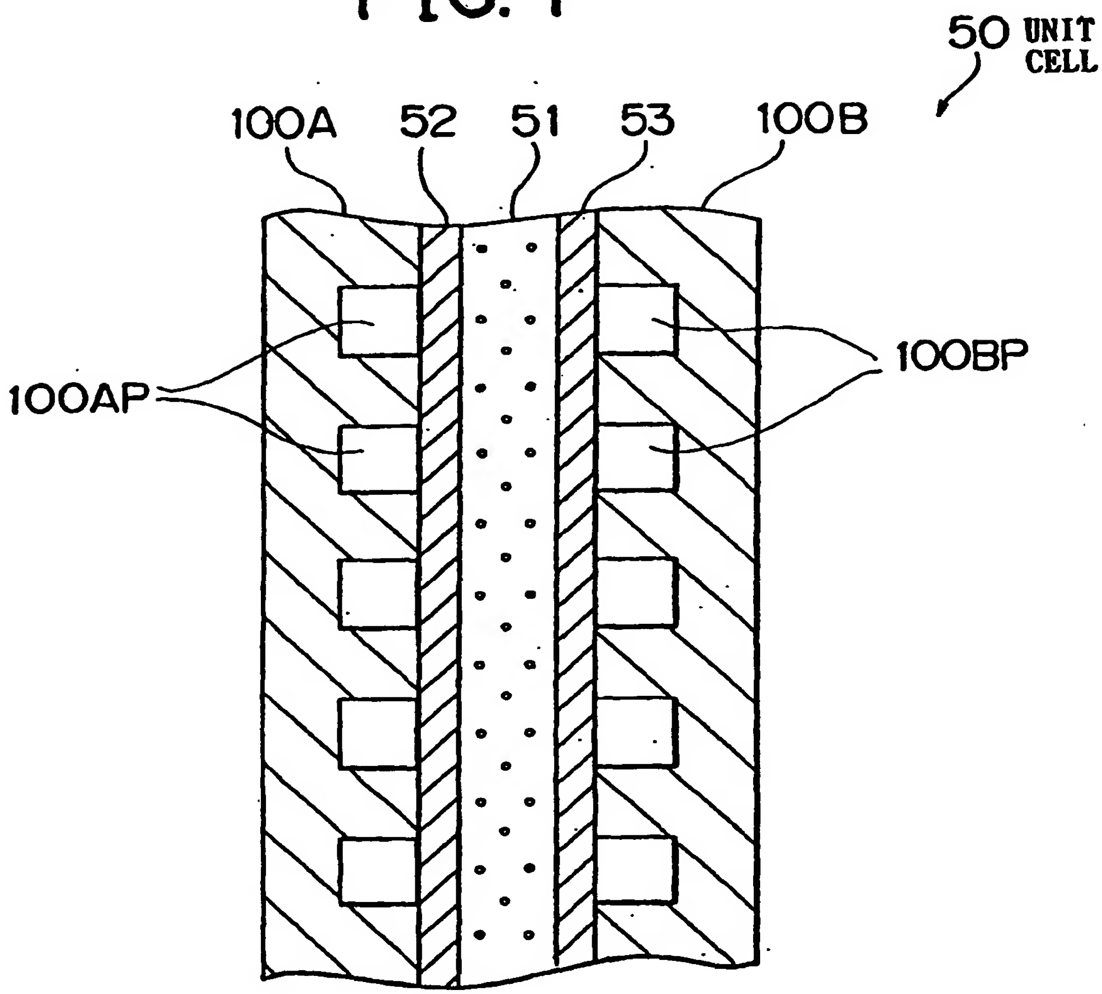


FIG. 2

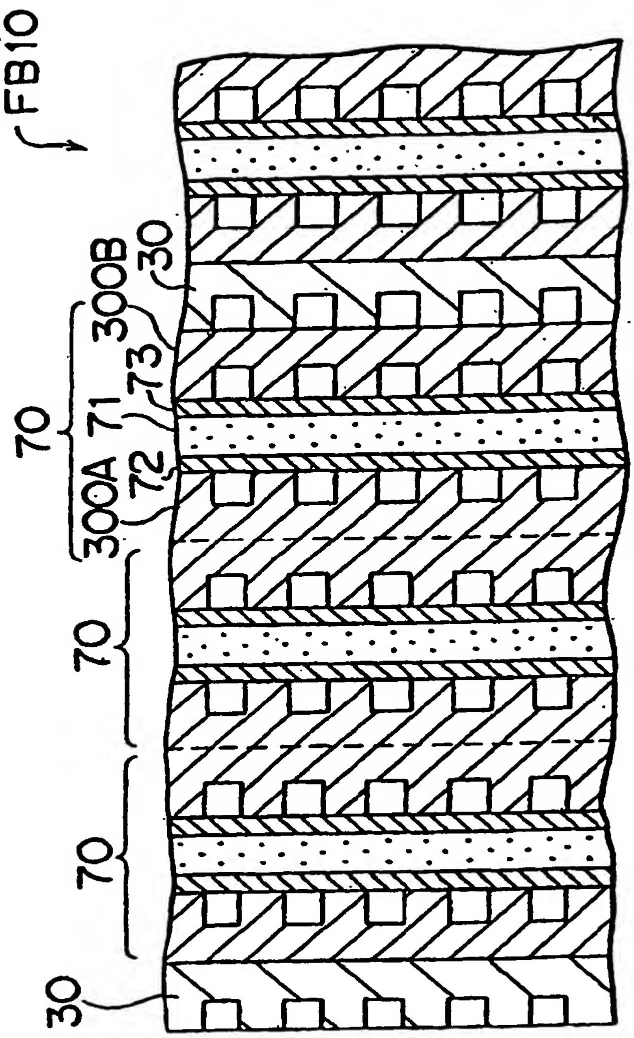


FIG. 3

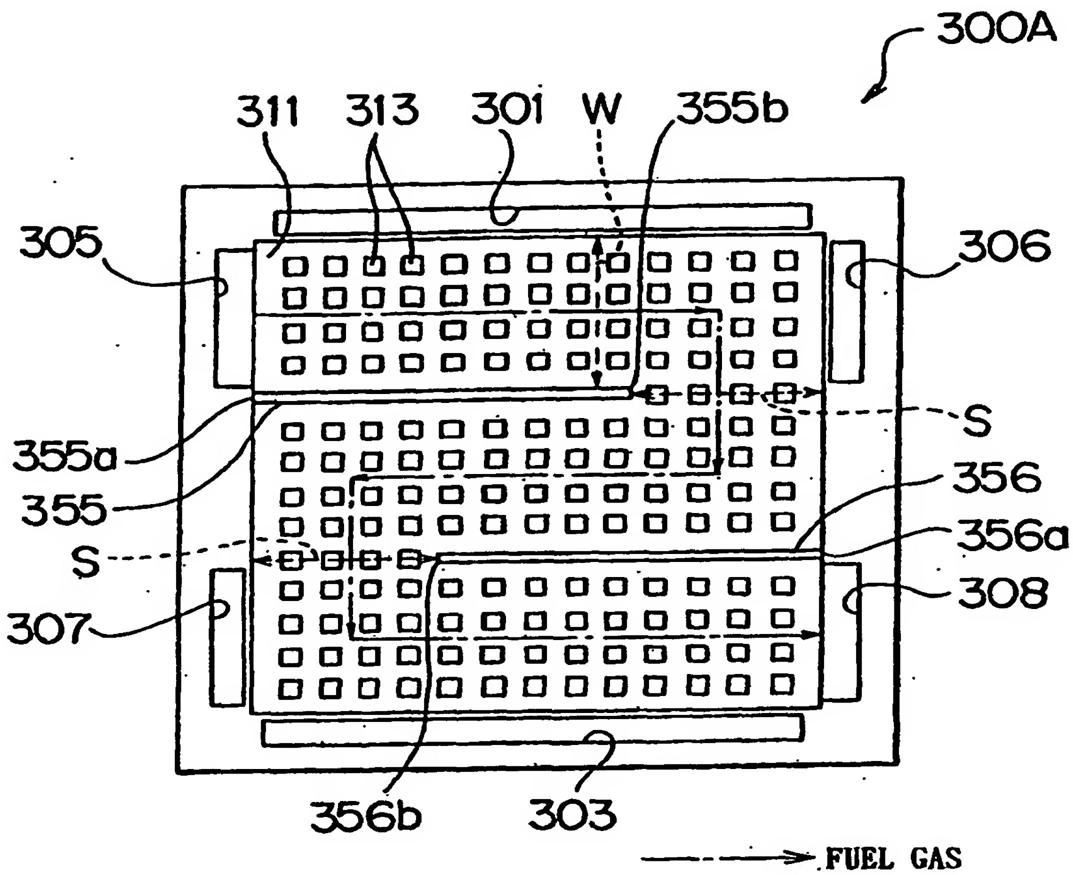
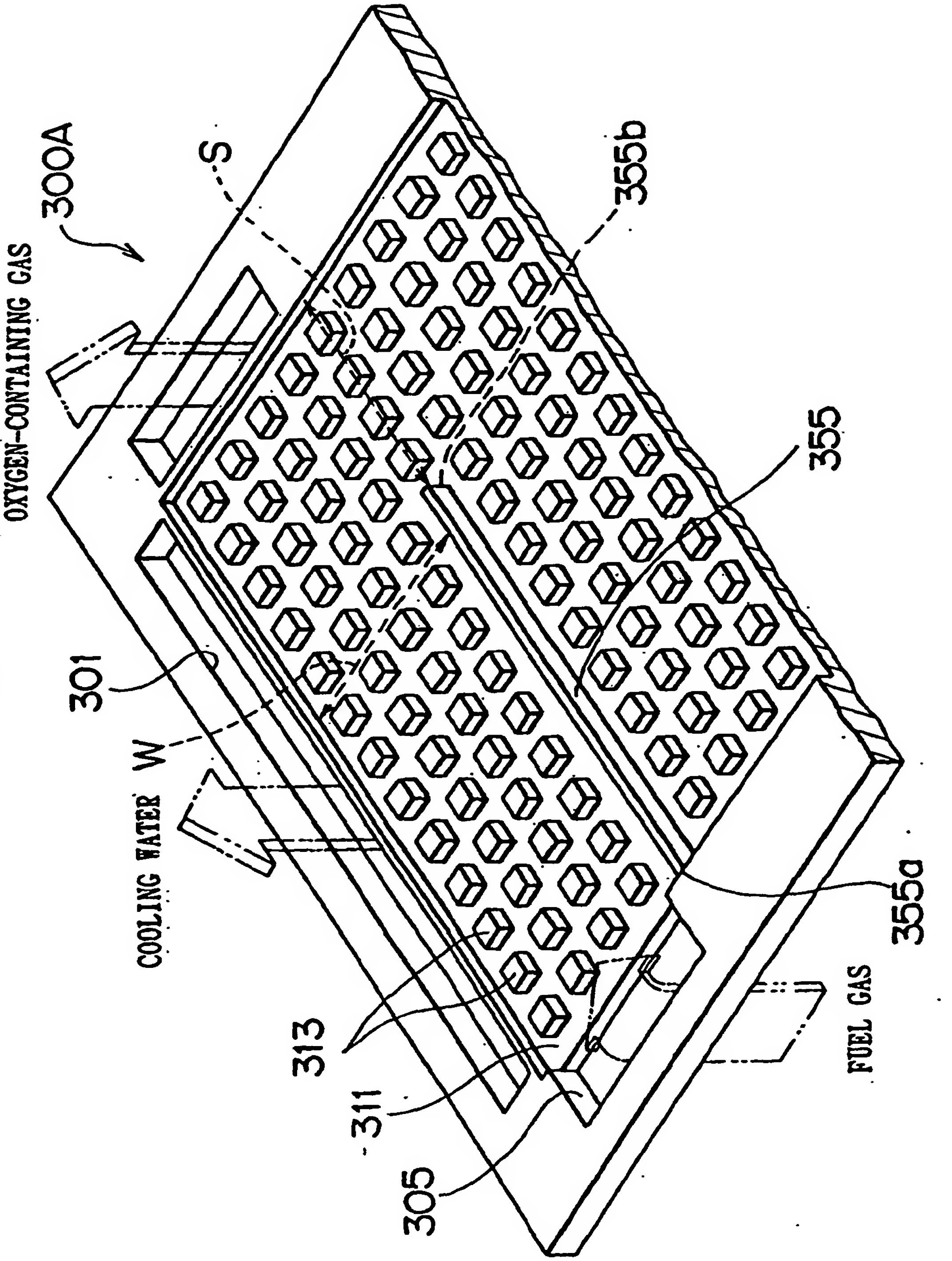

300A
311
313
301
W
355b
305
306
S
355a
356
355
356a
S
308
307
356b
303
FUEL GAS

FIG.4



300A
OXYGEN-CONTAINING GAS
S
355b
301
W
COOLING WATER
355
355a
313
311
305
FUEL GAS

FIG. 5

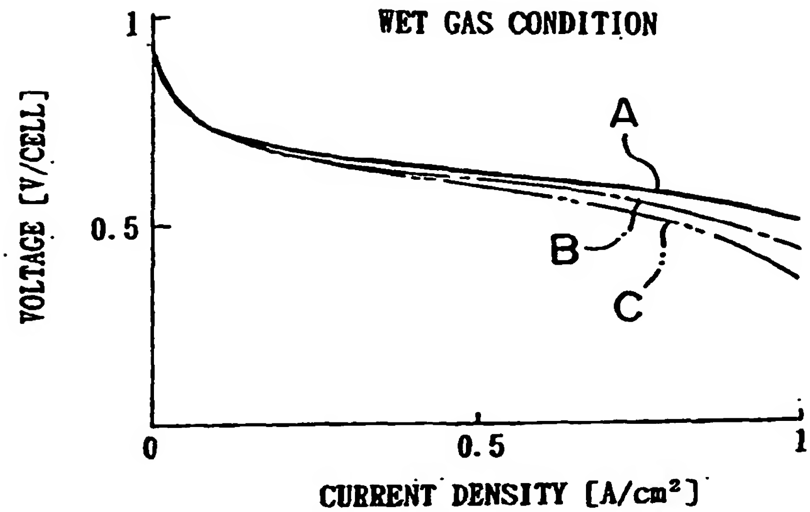

WET GAS CONDITION
1
0.5
VOLTAGE [V/CELL]
A
B
C
0
0.5
1
CURRENT DENSITY [A/cm²]

FIG. 6

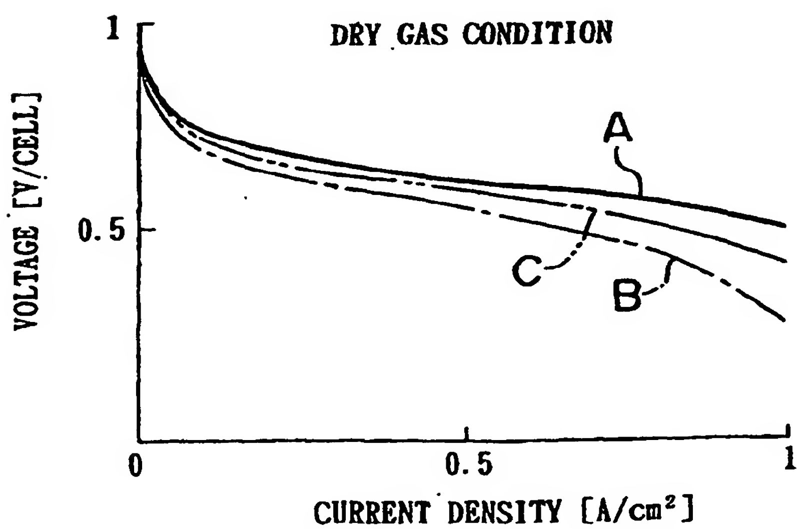

DRY GAS CONDITION
1
0.5
VOLTAGE [V/CELL]
A
C
B
0
0.5
1
CURRENT DENSITY [A/cm²]

FIG. 7

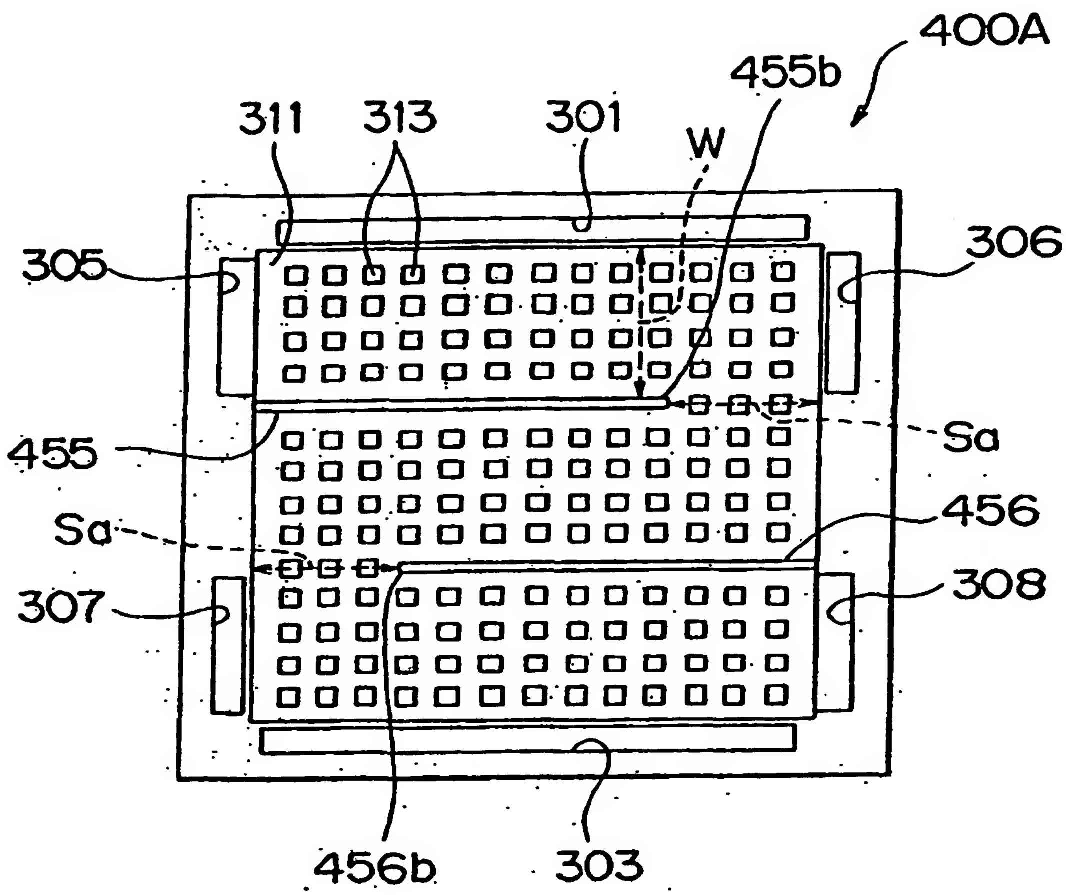


FIG. 8

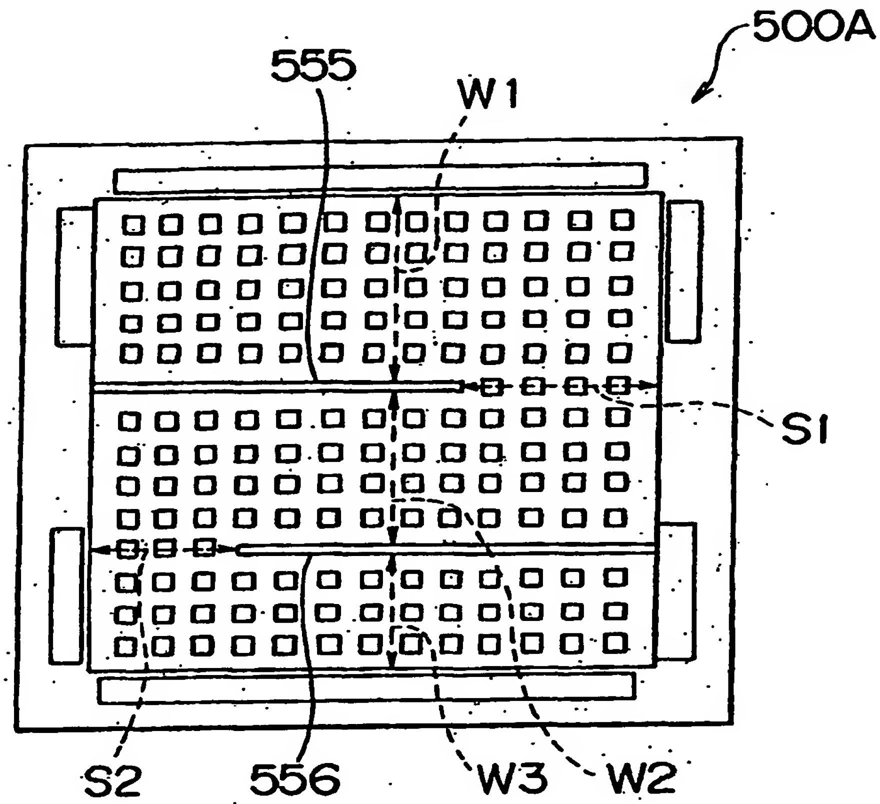


FIG. 9

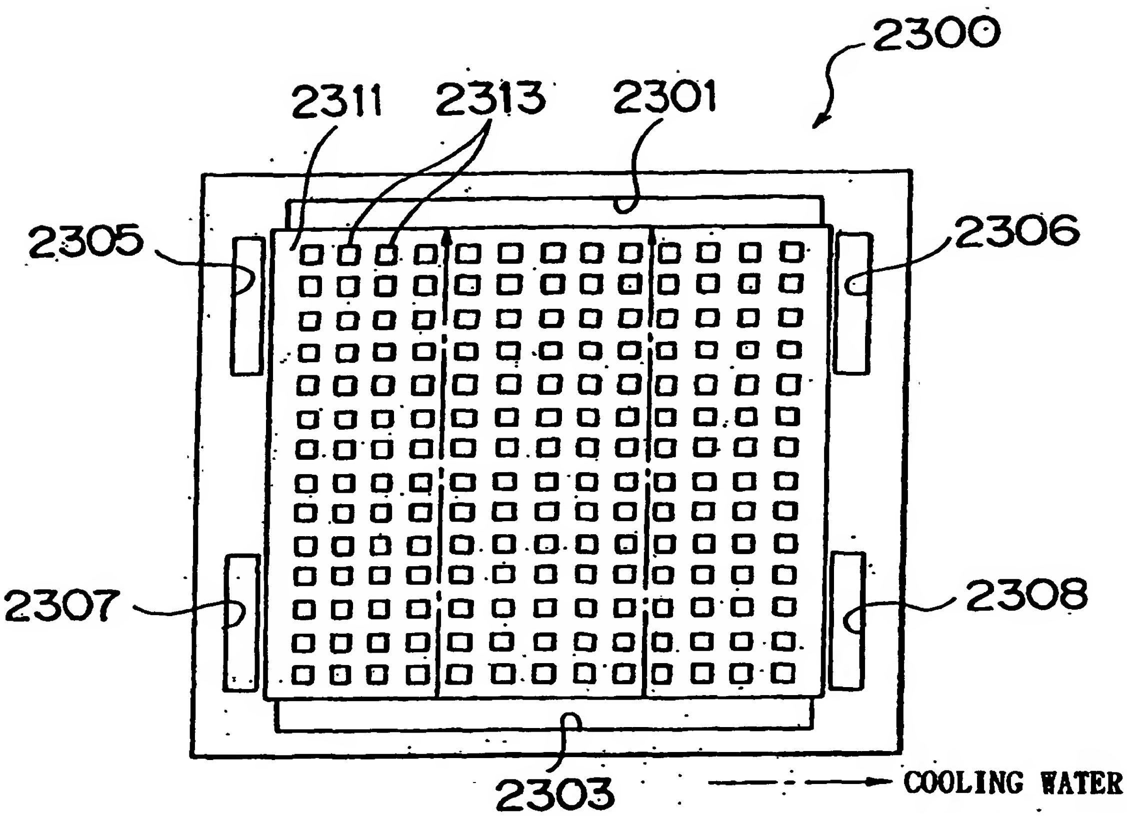


FIG. 10

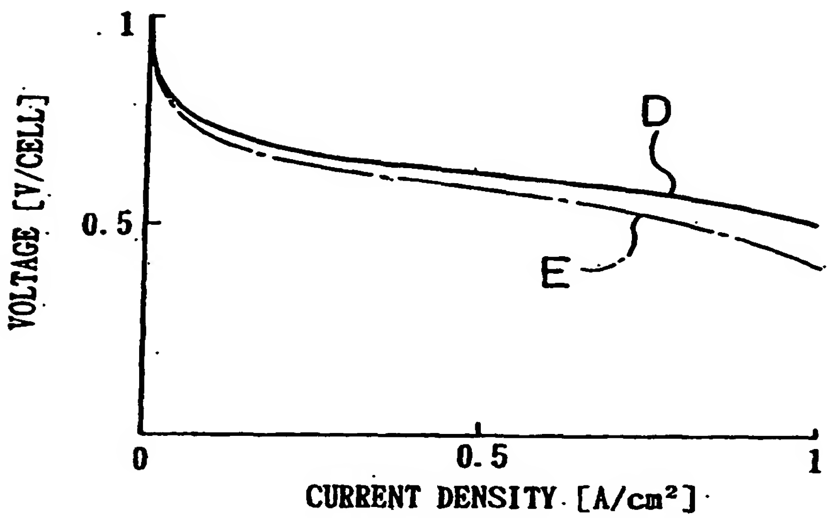


FIG. 11

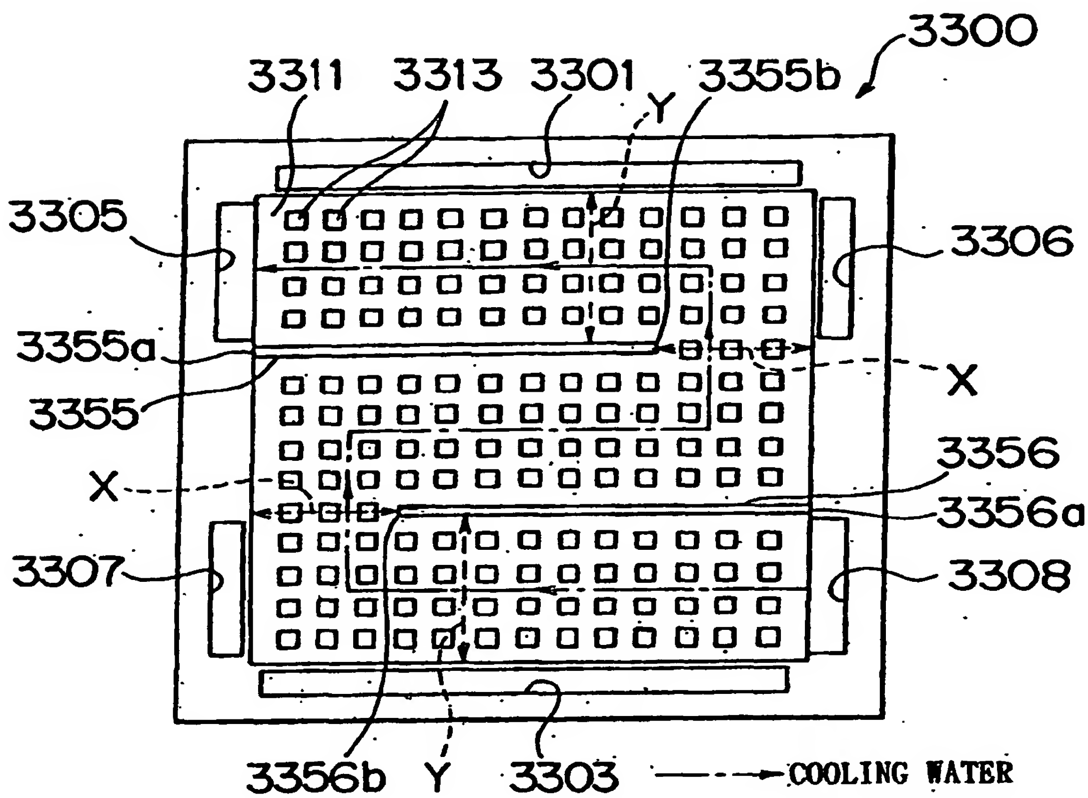

3300
3311
3313
3301
3355b
Y
3305
3306
3355a
X
3355
3356
X
3356a
3307
3308
3356b
Y
3303
COOLING WATER

FIG. 12

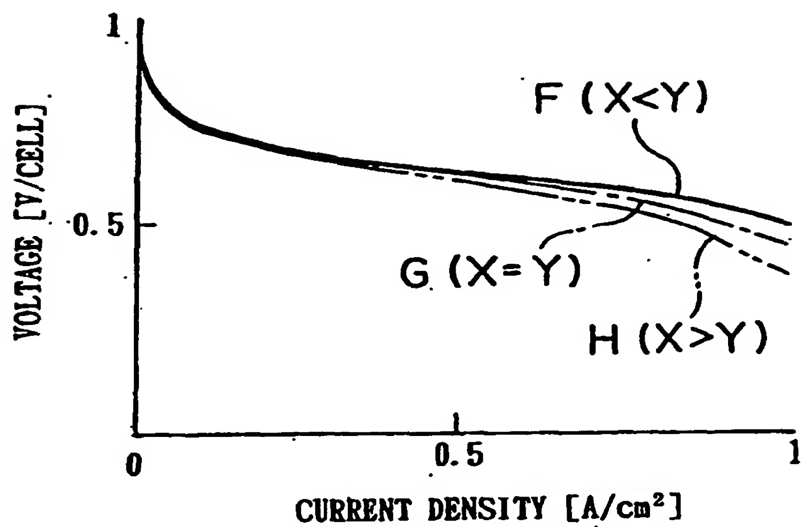


FIG. 13

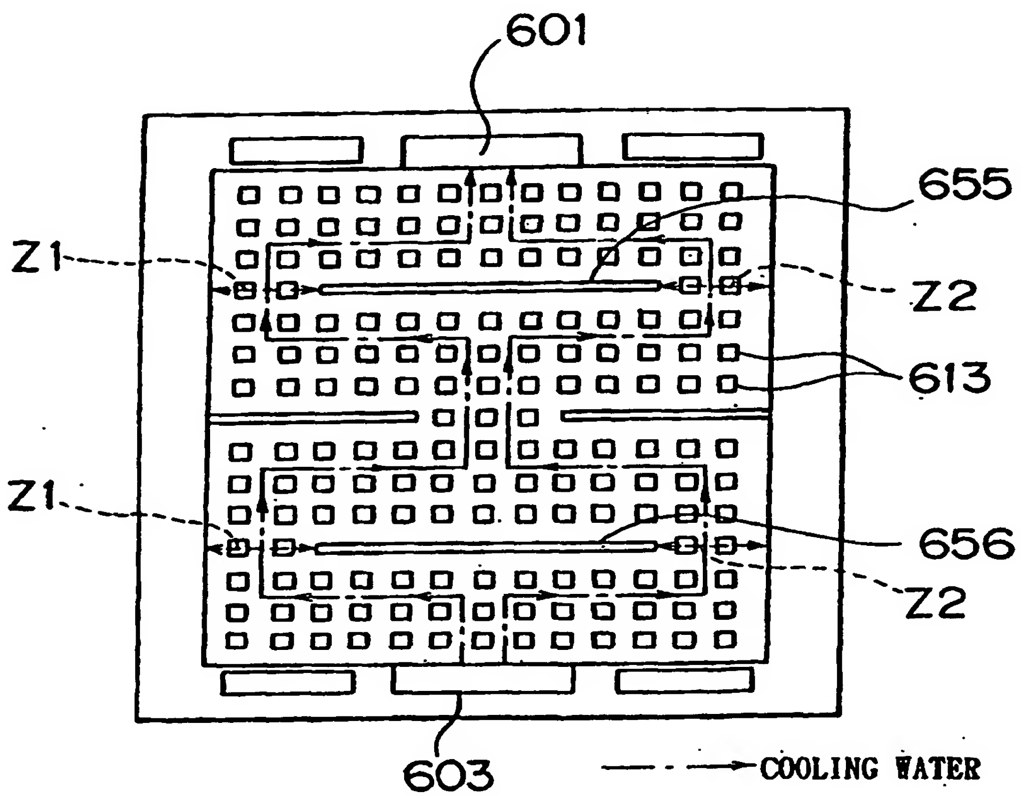


FIG. 14
RELATED ART

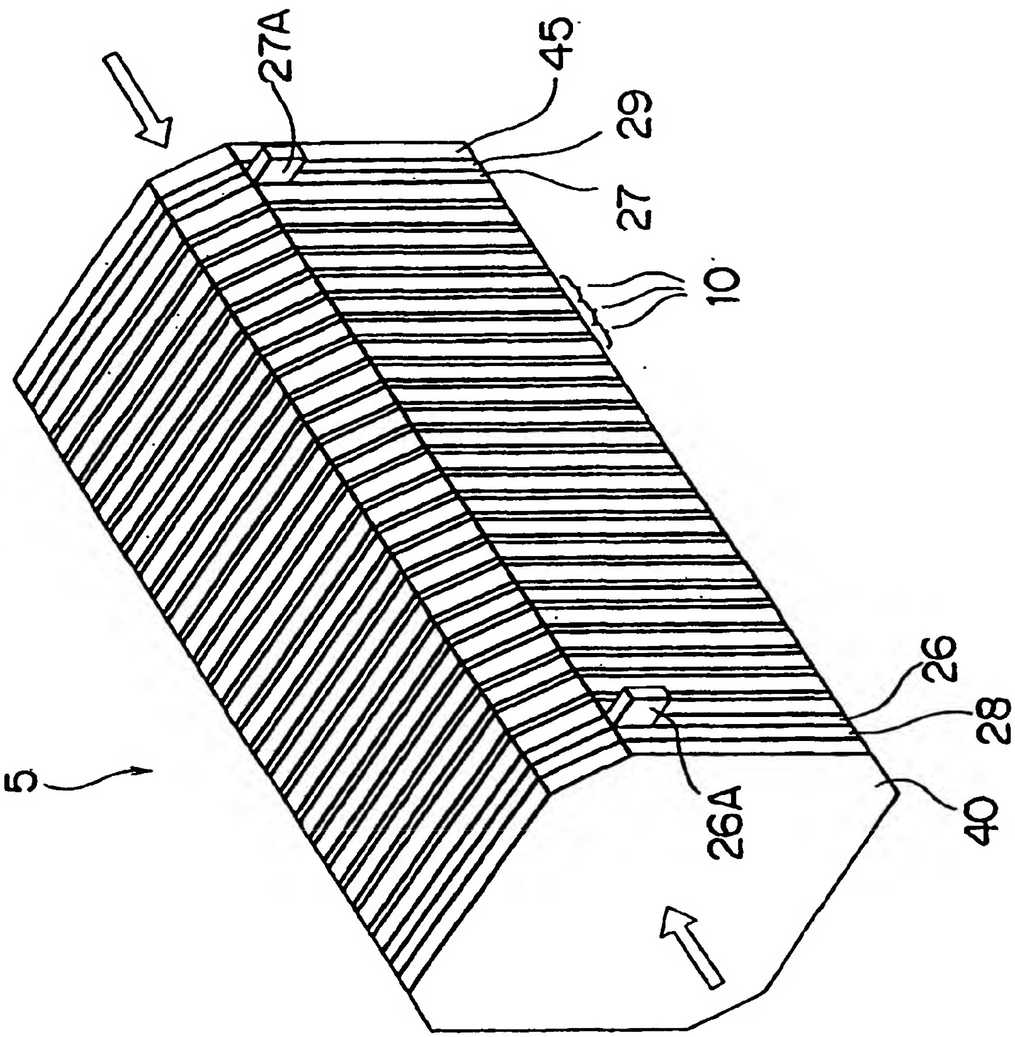


FIG.15

RELATED ART